NHP SAFETY REFERENCE GUIDE

440C

NHP

SAFETY FUNCTION
DOCUMENTS

Emergency Stop with
a Configurable Safety
Relay

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Safety Function Documents: 440C

Emergency Stop with a Configurable Safety Relay

Products: Emergency Stop, Guardmaster 440C-CR30 Configurable Safety Relay,
100S-C Safety Contactors
Safety Rating: CAT. 4, PLe to ISO 13849-1: 2008

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Introduction

This safety function application example explains how to wire and configure a Guardmaster® 440C-CR30 configurable safety relay to monitor a dual channel emergency stop (E-stop) device. If the E-stop is actuated, or a fault is detected in the monitoring circuit, the 440C-CR30 relay de-energizes the final control device, in this case, a redundant pair of 100S-C contactors.

Important User Information

Read this document and the documents listed in the additional resources section about installation, configuration, and

operation of this equipment before you install, configure, operate, or maintain this product. Users are required to

familiarize themselves with installation and wiring instructions in addition to requirements of all applicable codes, laws,

and standards.

Activities including installation, adjustments, putting into service, use, assembly, disassembly, and maintenance are required to be carried out by suitably trained personnel in accordance with applicable code of practice.

If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the

use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and

requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or

liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this manual.
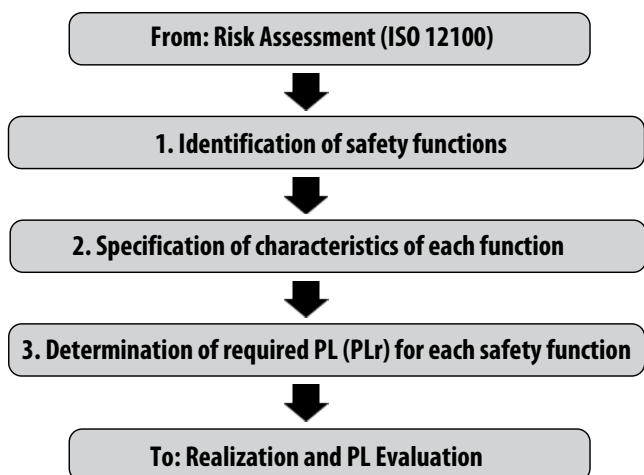
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Safety Function Realization: Risk Assessment

The required performance level is the result of a risk assessment and refers to the amount of the risk reduction to be carried out by the safety-related parts of the control system. Part of the risk reduction process is to determine the safety functions of the machine. In this application, the performance level required (PLr) by the risk assessment is Category 3, Performance Level d (CAT. 3, PLd), for each safety function. A safety system that achieves CAT. 3, PLd, or higher, can be considered control reliable. Each safety product has its own rating and can be combined to create a safety function that meets or exceeds the PLr.

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┌─────────────────────────────────────────┐
│   From: Risk Assessment (ISO 12100)      │
└─────────────────────────────────────────┘
                    ▼
┌─────────────────────────────────────────┐
│   1. Identification of safety functions  │
└─────────────────────────────────────────┘
                    ▼
┌─────────────────────────────────────────┐
│ 2. Specification of characteristics of each function │
└─────────────────────────────────────────┘
                    ▼
┌─────────────────────────────────────────┐
│ 3. Determination of required PL (PLr) for each safety function │
└─────────────────────────────────────────┘
                    ▼
┌─────────────────────────────────────────┐
│   To: Realization and PL Evaluation      │
└─────────────────────────────────────────┘
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Emergency Stop Safety Function

This application includes the safety function: Emergency stop by actuation of an emergency stop push button.

Safety Function Requirements

Pressing the emergency stop (E-stop) stops and prevents hazardous motion by removal of power to the motor. When the Estop button is reset, hazardous motion and power to the motor do not resume until a secondary action (start button depressed) occurs. Faults at the E-stop button, wiring terminals, or 440C-CR30 relay are detected before the next safety demand. This emergency stop function is complementary to any other safeguards on the machine and does not reduce the performance of other safety-related functions. The safety function in this example is capable of connecting and interrupting power to motors rated up to 12 A, 600V AC.

The safety function in this application technique meets or exceeds the requirements for Category 3, Performance Level d (CAT. 3, PLd), per ISO 13849-1 and control reliable operation per ANSI B11.19.

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General Safety Information

Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

⚠	**WARNING:** Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
⚠	**ATTENTION:** Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

Labels may also be on or inside the equipment to provide specific precautions.

⚡	**SHOCK HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
♨	**BURN HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.
💥	**ARC FLASH HAZARD:** Labels may be on or inside the equipment, for example, a motor control center, to alert people to potential Arc Flash. Arc Flash will cause severe injury or death. Wear proper Personal Protective Equipment (PPE). Follow ALL Regulatory requirements for safe work practices and for Personal Protective Equipment (PPE).

Contact NHP to find out more about our safety risk assessment services.

IMPORTANT	This application example is for advanced users and assumes that you are trained and experienced in safety system requirements.

⚠	**ATTENTION:** Perform a risk assessment to make sure all task and hazard combinations have been identified and addressed. The risk assessment can require additional circuitry to reduce the risk to a tolerable level. Safety circuits must take into consideration safety distance calculations, which are not part of the scope of this document.

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Functional Safety Description

Hazardous motion is interrupted or prevented by actuation of the emergency stop button. Each E-stop is considered a separate safety function. The E-stop button is connected to a pair of safety inputs on the 440C-CR30 relay. The safety contactors (K1 and K2) are connected to a pair of safety outputs.

The safety code in the 440C-CR30 relay monitors the status of the E-stop button by using a predefined function block named Safety Monitoring Function (SMF).

When all conditions are satisfied, no faults are detected on the inputs, and the reset push button is pressed, a second predefined function block called Safety Output Function (SOF) checks the status of the final control devices, a pair of 100S -C redundant contactors. The 440C-CR30 relay then issues an output signal to switch ON a pair of outputs to energize the safety contactors.

Bill of Material

| Catalog Number	Description	Quantity
1606-XLP72E	Compact power supply, 24…28V DC, 72 W, 120/240V AC / 85…375V DC input voltage	1
800F-1YP3	800F 1-hole enclosure E-stop station, plastic, PG, twist-to-release 40 mm, non-illuminated, 2 N.C.	1
1761-CBL-PM02	Cable: MicroLogix™ 1000 controller to personal computer	1
440C-CR30-22BBB	Guardmaster 440C-CR30 software configured safety relay, PLe SIL 3, 22 safety I/0 embedded serial port, USB programming port, 2 plug-in slots, 24V DC	1
800FP-R611PQ10V	800F reset, round plastic (type 4/4X/13, IP66), blue, R, plastic latch mount, 1 N.O. contact, 0 N.C. contact, low voltage, standard pack (Qty.1)	1
100S-C12EJ23BC	MCS 100S-C safety contactor, 12 A, 24V DC (with electric coil), bifurcated contact	2
2080-IQ4OB4	4-channel digital input/output combination module	1

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Setup and Wiring

For detailed information on installing and wiring, refer to the publications listed in the Additional Resources on the back cover.

System Overview

The 440C-CR30 relay monitors the inputs from the E-stop. Typically, E-stops are not operated as often as a safety gate, and are considered to be a complementary safety device.

EN 12100-2 5.5.1 provides details on complementary protective measures. These are measures which are neither inherently safe design nor safeguarding, but are required due to intended use or reasonably foreseeable misuse of the machine. The circuit is tested by using test pulses (MP_12 and MP_13) on the inputs, EI_00 and EI_01. These test pulses source the 24V DC for the circuit. By periodically dropping the 24V DC to 0V DC, it is possible to detect cross-channel faults and shorts to an external 24V DC. Shorts to 0V DC are seen as an open circuit by the input and are detected by the appropriate safety function block in the application code.

The final control device in this case is a pair of 100S-C safety contactors, K1 and K2. The contactors are wired in a redundant configuration and are tested on startup for faults. The start-up test is accomplished by using a Safety Output Function (SOF) function block to monitor the feedback circuit wired into standard inputs P1_00 and P1_01 before the contactors are energized. The system is reset by means of the momentary push button, PB1.

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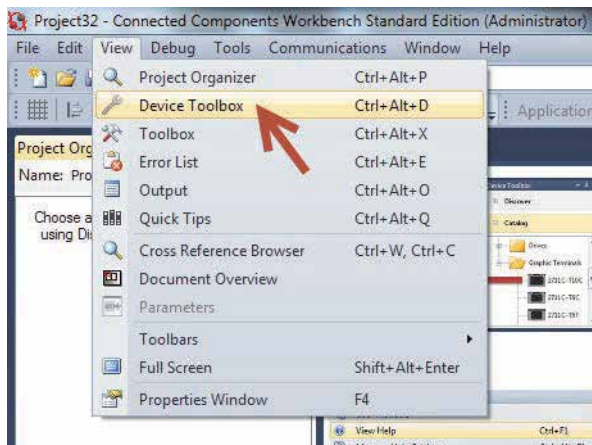Safety Rating: CAT. 4, PLe to ISO 13849-1: 2008

Electrical Schematic
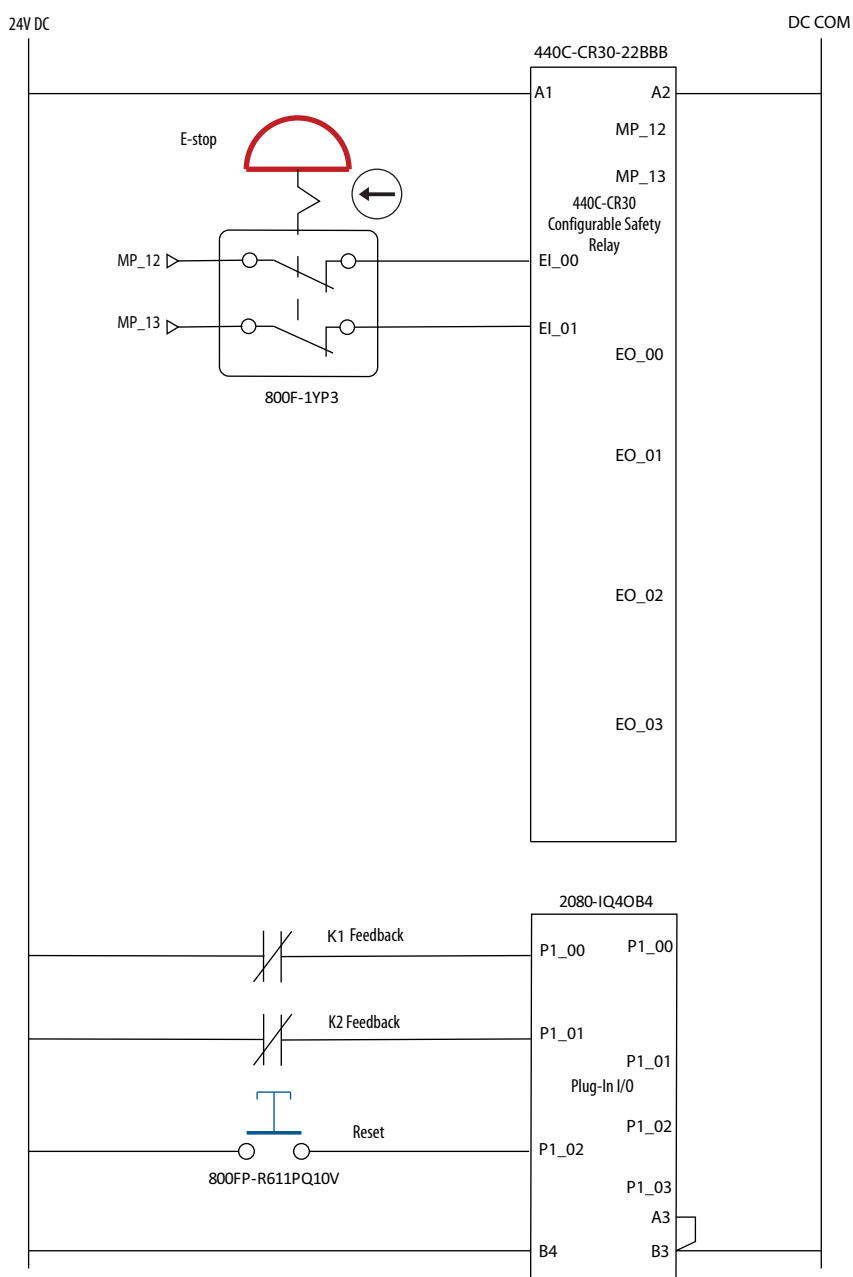
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Electrical Schematic
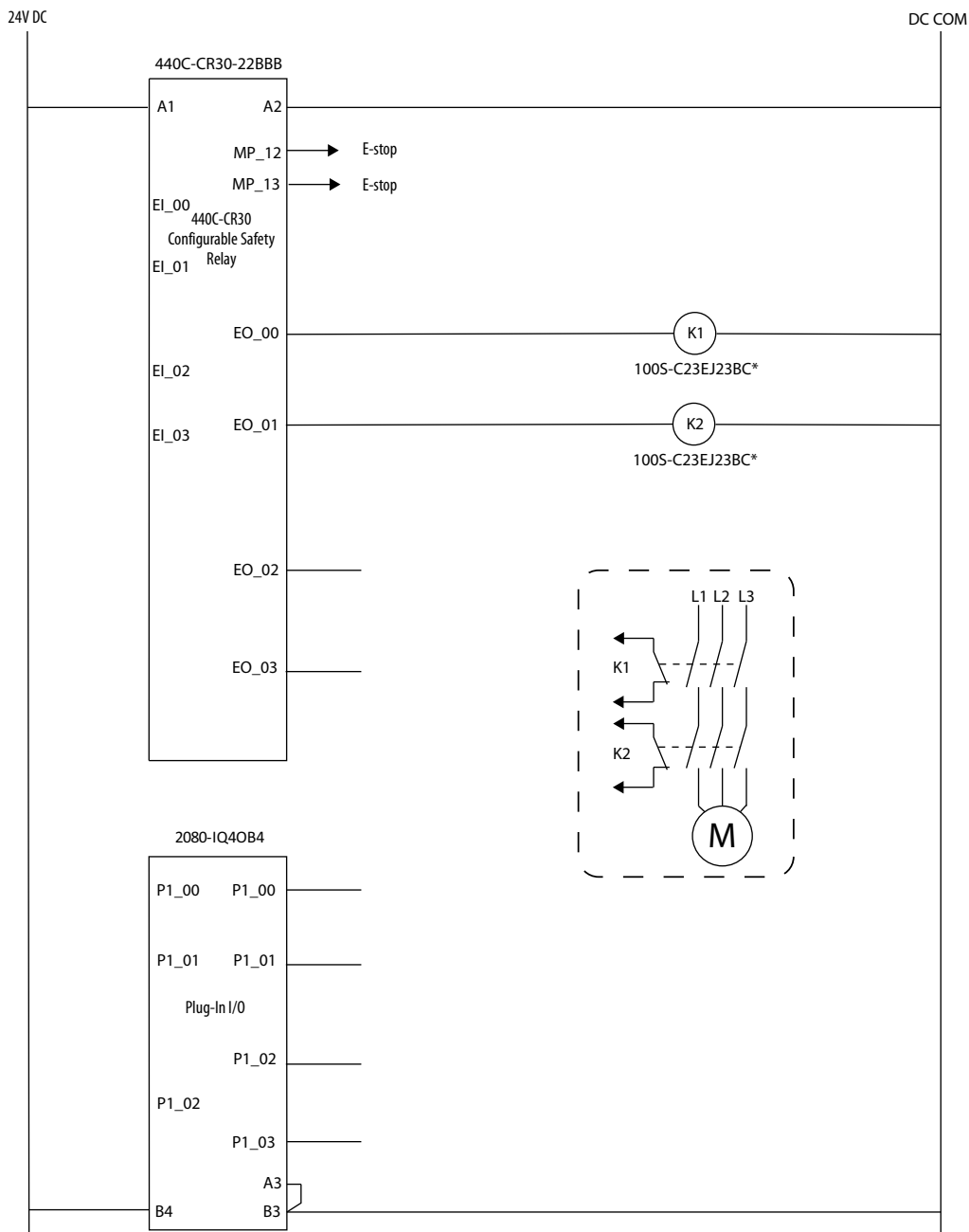
* ISO 13849-2 requires transient suppression across the load as a Basic Safety Principal.
The 'EJ' electronic coil provides suitable suppression.

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Configuration

The 440C-CR30 relay is configured by using Connected Components Workbench™ software, release 6.01 or later. A detailed description of each step is beyond the scope of this document. Knowledge of the Connected Components Workbench software is assumed.

Configure the 440C-CR30 Relay

Follow these steps to configure the Guardmaster 440C-CR30 relay by using the Connected Components Workbench software.

1. In Connected Components Workbench software, choose View and then Device Toolbox.

2. Select 440C-CR30-22BBB.
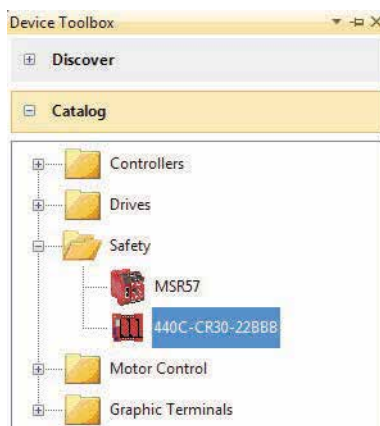
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Configure the 440C-CR30 Relay *cont*

3. In the Project Organizer, double-click the Guardmaster_440C_CR30 relay.

4. To add the plug-in I/O module called for in the schematic, right-click the left plug-in module space and choose the 2080-IQ4OB4 module.

TIP: The I/O module is shown in standard gray because it is not a safety I/O module. That is permissible in this application because the standard I/O module is not used to connect safety signals. Inputs such as Feedback and Reset button are not considered strict, safety signals. Using the standard I/O module for these non-safety signals can reserve the limited number of safety inputs and outputs for true safety signals.

5. Click the Edit Logic button to open the Connected Components Workbench Workspace.

6. From the View pull-down menu, choose Toolbox.
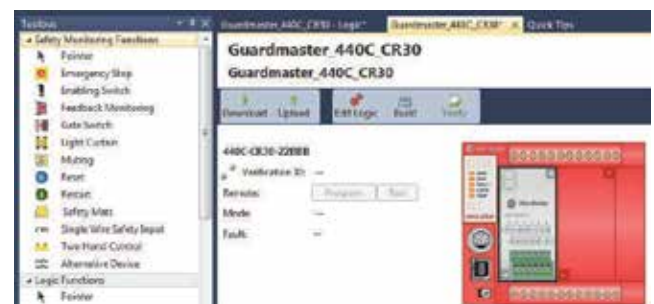
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Configure the Inputs

Follow these steps to configure the inputs.

1. Select Emergency Stop.
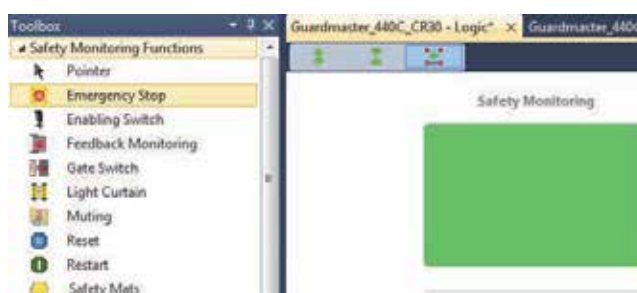
2. Drag it to the green rectangle under Safety Monitoring and release it.

Connected Components Workbench software has assigned input terminals EI_00 and EI_01 on the left side of the block. The software automatically assigns the next unused terminal for a newly-added device. The terminals can be changed to any unused input terminal, but in this case, leave the default. Because an E-stop is an electro-mechanical device, the software has automatically added terminals 12 and 13 as test sources. Numbers 12 and 13 refer to multipurpose terminals 12 and 13 (MP_12 and MP_13).

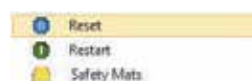3. Add a Feedback Monitoring input.

Notice that the software assigns it to the next available input terminal, which in this case is EI_02.

4. Change the number of inputs to 2, and use the Input pull-down menu to select plug-in inputs 00 and 01 instead.
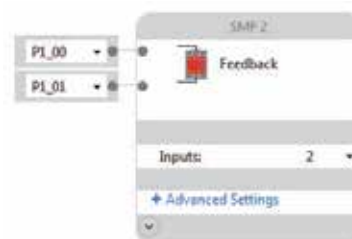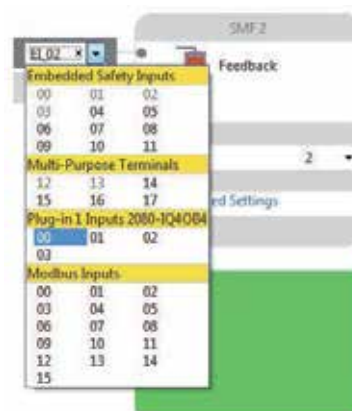
5. Add a Reset.

6. Change the Reset input to Plug-In input 02 to complete the configuration of the inputs.

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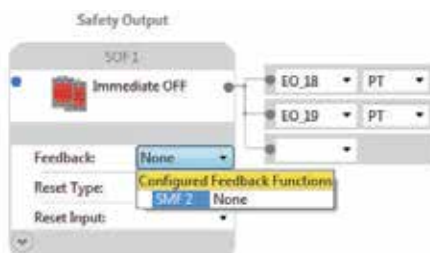
Configure the Outputs

Follow these steps to configure the safety and diagnostic outputs.

1. Select and drag the Immediate OFF Safety Output function block to the top position in the Safety Output column of the Workspace.
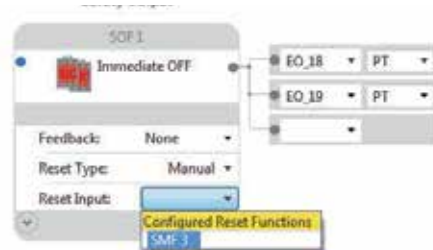

The software automatically assigns two outputs to the next available safety outputs, which in this case are E0_00, and E0_01, and leaves one blank, unassigned output. One, two, or three outputs may be configured. Because we are using E0_00 and E0_01 as our outputs, no I/O changes are required.

2. Change the Feedback input to SMF 2.

3. Change the Reset Input to SMF 3.

Configuration of the safety outputs is complete.

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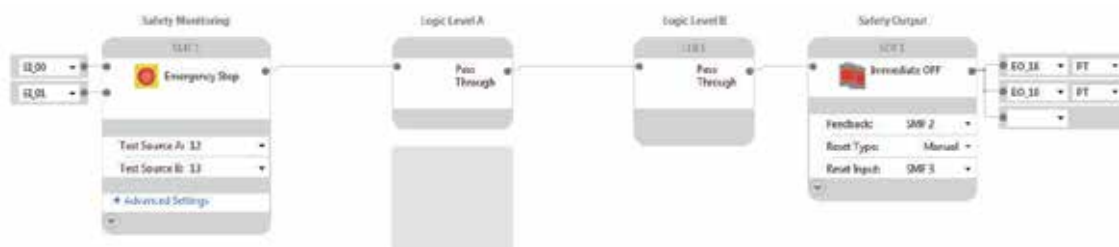
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Configure the Logic

The logic ties the inputs to the outputs, making the outputs respond to the inputs in the manner required.

1. Click the blue dot on the E-stop input block, and notice that it turns gray.
2. Click the blue dot on the Immediate OFF output block to connect the blocks.

The software automatically adds the Pass Through blocks because no additional Logic Functions are being used.

The complete logic appears as follows.

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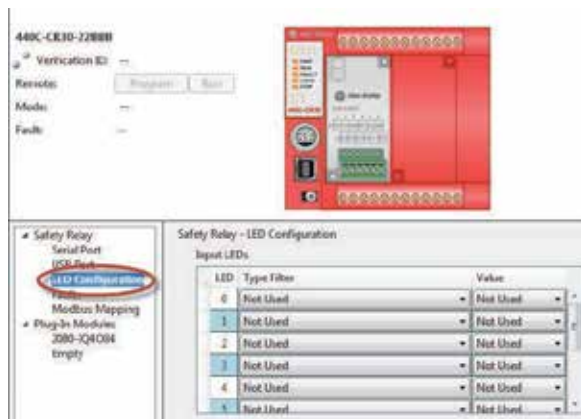
Configure the Status Indicators

The 440C-CR30 relay lets you configure ten input status indicators and six output status indicators. These status

indicators can be very helpful while testing the system during installation and commissioning. They are also useful for

monitoring the system during operation.

To configure LED status indicators to show the status of the E-stop (Terminals 00 and 01), follow these steps.
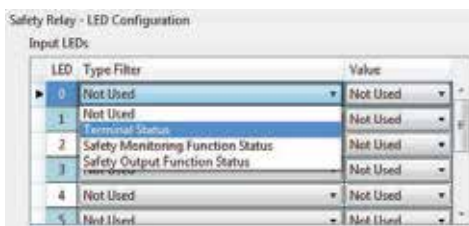
1. Click Guardmaster_440C_CR30.

2. Select LED configuration.

3. Choose Terminal Status as the Type Filter for LED 0.

4. Select Terminal 00 as the Value for LED 0.

5. Configure the remaining Input LED status indicators as shown.

6. Configure the Output LED status indicators as shown.

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Confirm the Validity of the Build

Follow these steps to confirm the validity of the logic by using the Build feature in Connected Components Workbench software.

1. Click Guardmaster_440C_CR30 in the bar above the Workspace.
2. Click Build.

Build Succeeded message confirms that the configuration is valid

If an error or omission is discovered during a build, a message is displayed which details the error so that it may be corrected. After you correct the error, you need to perform the build again.

Save and Download the Project

Follow these steps to save and download the project.

1. From the File menu, choose Save as to save the project.

   IMPORTANT Saving the project with a new name closes the workspace window(s).

2. In the Project Organizer window, double click Guardmaster_440C_CR30 to open the workspace.
3. Power up the 440C-CR30 safety relay.
4. Connect the USB cable to the 440C-CR30 relay.
5. Click Download

6. In the Connection Browser, expand the AB_VBP-1 Virtual Chassis and select the Guardmaster 440C-CR30-22BBB.

7. Click OK.
8. Click Yes to change from Run to Program mode.

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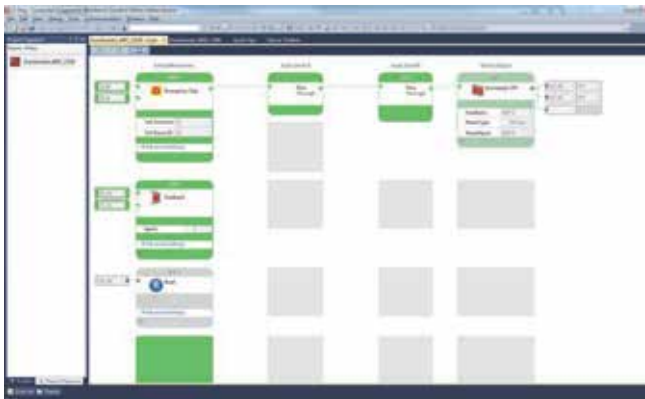
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Save and Download the Project *cont*

9. When the download is complete, click Yes to change from Program to Run mode.

10. Click Edit Logic to see the online diagnostics.

Green indicates that a block is True or that an input or output terminal is ON. Flashing green indicates that a Safety

Output Function is ready to be Reset.

The online diagnostics mode of the 440C-CR30 relay can be very helpful during the verification process.

11. Review the information in Calculation of the Performance Level on page 18 and Verification and Validation Plan on page 20 before proceeding with Verification of the Configuration on page 22.

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Calculation of the Performance Level

When properly implemented, the emergency stop safety function can achieve a safety rating of Category 4, Performance
Level e (CAT. 4, PLe), according to ISO 13849-1: 2008, as calculated by using the SISTEMA software PL calculation tool.
The Performance Level required (PLr) from the risk assessment for the emergency stop safety function in this application is PLd

The Performance Level and Category achieved by each subsystem of the emergency stop safety function, as calculated by
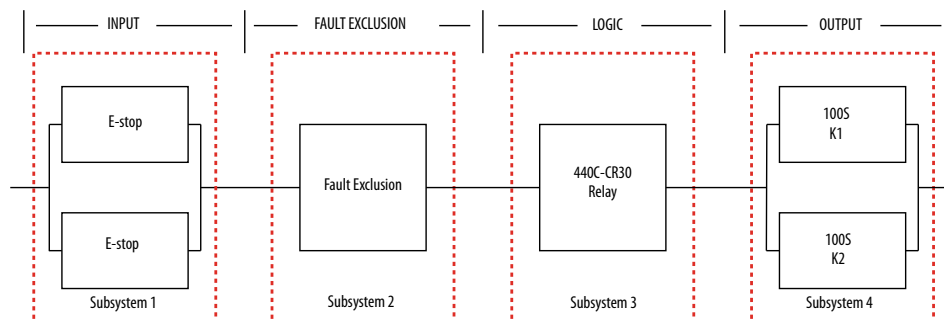SISTEMA, is shown below:

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Calculation of the Performance Level *cont*

The emergency stop safety function can be modeled as follows.

Because these are electro-mechanical devices, the safety contactors data includes the following:

- Mean Time to Failure, dangerous (MTTFd)
- Diagnostic Coverage (DCavg)
- Common Cause Failure (CCF)
- Electro-mechanical devices' functional safety evaluations include the following:
    – How frequently they are operated
    – Whether they are effectively monitored for faults
    – Whether they are properly specified and installed

SISTEMA calculates the MTTFd by using B10d data provided for the contactors along with the estimated frequency of use, entered during the creation of the SISTEMA project.

The DCavg (99%) for the contactors is selected from the Output Device table of ISO 13849-1 Annex E, Direct Monitoring.

The DCavg (99%) for the E-stop is selected from the Input Device table of ISO 13849-1 Annex E, Cross Monitoring.

The CCF value is generated by using the scoring process outlined in Annex F of ISO 13849-1. The complete CCF scoring process must be performed when actually implementing an application. A minimum score of 65 must be achieved.

The emergency stop function is a complementary protective measure which is intended to be used in conjunction with other safeguarding measures and protective devices to sufficiently reduce risk. The emergency stop function is designed not to impair the effectiveness of the other protective devices or safety functions. For emergency stop devices in accordance with IEC 60947-5-5, a fault exclusion for mechanical aspects is allowed up to PLd if the maximum number of operations is considered. However, the actual number of operations (NOP) is used for the purposes of the MTTFd calculation in this document.

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Verification and Validation Plan

Verification and validation play important roles in the avoidance of faults throughout the safety system design and development process. ISO 13849-2 sets the requirements for verification and validation. The standard calls for a documented plan to confirm all of the safety functional requirements have been met.

Verification is an analysis of the resulting safety control system. The Performance Level (PL) of the safety control system is calculated to confirm that the system meets the required Performance Level (PLr) specified. The SISTEMA software is typically used to perform the calculations and assist with satisfying the requirements of ISO 13849-1.

Validation is a functional test of the safety control system to demonstrate that the system meets the specified requirements

of the safety function. The safety control system is tested to confirm that all of the safety-related outputs respond

appropriately to their corresponding safety-related inputs. The functional test includes normal operating conditions in addition to potential fault injection of failure modes. A checklist is typically used to document the validation of the safety control system.

Before validating the system, confirm that the Guardmaster 440C-CR30 configurable safety relay is wired and configured in accordance with the installation instructions.

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Verification and Validation Checklist

GENERAL MACHINERY INFORMATION	
Machine Name / Model Number	
Machine Serial Number	
Customer Name	
Test Date	
Tester Name(s)	
Schematic Drawing Number	
Configurable Relay Name	
Safety Verification ID	

Guardmaster 440C-CR30 Safety System Configuration and Wiring Verification			
Test Step	Verification	Pass/Fail	Changes/Modifications
1	Verify that the safety system has been designed in accordance with the Guardmaster 440C-CR30 User Manual. Refer to Additional Resources on page 24.		
2	Visually inspect the safety system connection and I/O module to make sure they are wired as documented in the schematics.		
3	Visually inspect the Connected Components Workbench program to verify that the safety system connection and I/O module are configured as documented.		
4	Visually inspect the Connected Components Workbench application program to verify that suitable safety instructions are used.		
5	All input devices are qualified by cycling their respective actuators. Monitor their status in the Connected Components Workbench software.		
6	All output devices are qualified by cycling their respective actuators. Monitor their status in the Connected Components Workbench software.		

Normal Operation Verification - The Guardmaster 440C-CR30 safety system properly responds to all normal Start, Stop, E-stop and Reset commands.			
E-stop Input Tests			
Test Step	Verification	Pass/Fail	Changes/Modifications
1	While the system is running, remove the channel 1 wire. Both contactors should deenergize. Verify proper machine status indication and Connected Components Workbench safety application program indication. Restore channel 1 and repeat for channel 2.		
2	While the system is running, short channel 1 to 24V DC. Both contactors should deenergize. Verify proper machine status indication and Connected Components Workbench safety application program indication. Restore channel 1 and repeat for channel 2.		
3	While the system is running, short channel 1 to 0V DC. Both contactors should deenergize. Verify proper machine status indication and Connected Components Workbench safety application program indication. Restore channel 1 and repeat for channel 2.		
4	While the system is running, short channels 1 and 2. Both contactors should de-energize. Verify proper machine status indication and Connected Components Workbench safety application program indication. Restore channel 1 and 2 wiring		
Safety Contactor Output Tests			
Test Step	Verification	Pass/Fail	Changes/Modifications
1	Initiate a Start command. Both contactors should energize for a normal machine run condition. Verify proper machine status indication and Connected Components Workbench safety application program indication.		
2	While the system is running, remove the contactor feedback from the safety I/O module. All contactors should remain energized. Initiate a Stop command and attempt a Reset command. The system should not restart or reset. Verify proper machine status indication and Connected Components Workbench safety application program indication.		
3	While the system is running, short the contactor feedback to the safety I/O module. All contactors should remain energized. Initiate a Stop command and attempt a Reset command. The system should not restart or reset. Verify proper machine status indication and Connected Components Workbench safety application program indication.		

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Verification of the Configuration

The system must verify the configuration of each individual application by using the Verify command. If the 440C-CR30 configuration safety relay is not verified, it will fault after 24 hours of operation.

ATTENTION: The verification process should be documented in the safety system's technical file.

Follow these steps to download and verify the configuration.

1. Make sure the 440C-CR30 relay is powered up and connected to your workstation via the USB cable.

2. Confirm that the upper right-hand corner of the Connected Components Workbench Project tab shows that the 440C-CR30 relay is connected. If it is not, click Connect to Device to establish the software connection

3. Click Verify.

4. Answer all the questions and check each box, if completed.
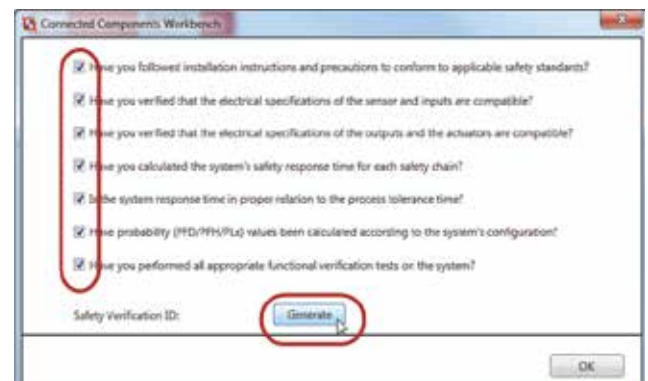
IMPORTANT: All of the boxes must be marked in order to Generate the Verification ID.

5. Click Generate.

6. Click Yes to proceed with the verification.

7. Click Yes to change to Run mode.
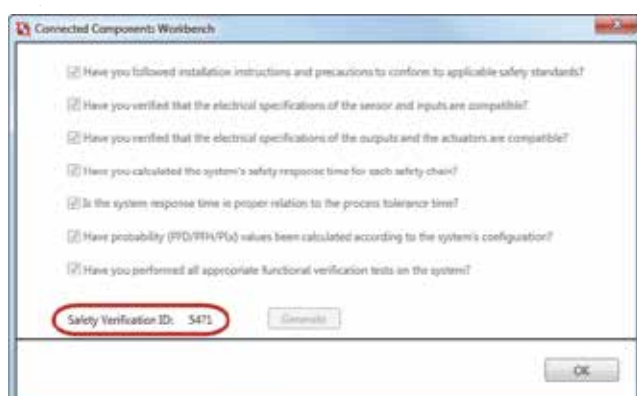
Safety Function Documents: 440C

Emergency Stop with a Configurable Safety Relay

Products: Emergency Stop, Guardmaster 440C-CR30 Configurable Safety Relay, 100S-C Safety Contactors
Safety Rating: CAT. 4, PLe to ISO 13849-1: 2008

Verification of the Configuration

8. Record the Safety Verification ID in the machine's documentation.

This process is the feedback to the 440C CR30 relay that the system verification and functional tests have been completed. The unique verification ID can be used to check if changes have been made to a configuration file. Any change to the configuration removes the Safety Verification ID. Subsequent Verify actions generate a different verification ID. The Safety Verification ID is displayed in Connected Components Workbench software only when you are connected to the 440C-CR30 relay.

Additional Resources

These documents contain additional information concerning related products from Rockwell Automation.

Resource	Description
Guardmaster 440C-CR30 Configurable Safety Relay User Manual, publication **440C-UM001**	Provides detailed information on how to install, configure, operate, and troubleshoot a Guardmaster 440C-CR30 configurable safety relay.
Guardmaster 440C-CR30 Software Configurable Safety Relay Quick Start Guide, publication **440C-QS001**	Provides information on how to configure a Guardmaster 440C-CR30 configurable safety relay to communicate with a Panelview™ Component terminal via Modbus communication protocol.
Industrial Automation Wiring and Grounding Guidelines, publication **1770-4.1**	Provides general guidelines for installing a Rockwell Automation® industrial system.
Rockwell Automation Safety Products Catalog, available from the Product Catalogs link at **http://www.ab.com**	Provides information on safety products available from Rockwell Automation.
Product Certifications website, **http://www.ab.com**	Provides declarations of conformity, certificates, and other certification details.
The SISTEMA Cookbook 4, available at **http://www.dguv.de/ifa/Praxishilfen/Software/SISTEMA/SISTEMA-Kochb%C3%BCcher/index-2.jsp.**	Provides details on how to model safety functions in the SISTEMA tool.

You can view or download publications at http://www.rockwellautomation.com/literature/. To order paper copies of technical documentation, contact your local Allen-Bradley distributor or Rockwell Automation sales representative